Comments on a Review of the Design of Primary Beamline Instrumentation
August 14, 2001

Introduction and Specifications Summary
Presenter: S. Childress

1. (Reviewer: C. Brown) I believe that a set of beam halo counters should be included in the monitoring system - despite the one turn spill.

Halo foils are included in the UT-Austin profile monitor design.

2. (Reviewer: B. Foster) By far the biggest system problem is the 1E-6 "allowable beam loss" situation in the carrier pipe. NUMI management should aggressively pursue multiple avenues to achieve a workable solution, including:

    a. Getting the specification changed via more accurate radiological calculations.
    b. Halo scraping of the circulating beam in the main injector (probably also be needed for slow extraction to Meson 120). Both momentum and betatron scraping are desirable due to the high dispersion in the carrier pipe region.
    c. Plans for primary & secondary collimation of the extracted beam before it reaches the carrier pipe region, primarily to eliminate "worst-case accidents" in the carrier pipe region.
    d. Understanding the effect of slip-stacking on the momentum spread and losses.
    e. Consider optics changes to increase the momentum acceptance of the line, for example placing a (permanent magnet?) quadrupole in the middle of the "uninhabitable" carrier pipe region.

Radiological calculations are fairly accurate, however unknowns such as ground water flow through rock cracks drive some of the specifications. The beamline optics was re-designed to accept the full dynamic aperture of the Main Injector. Halo scraping may eventually be necessary in the Main Injector at higher intensities with slip stacking.

3. (Reviewer: B. Foster) Will the Beamline Tuner Program run off of multiwires, BPM's or both? How will the switchover be handled? A specification for the beam line tuner program would be useful to begin to estimate software labor costs.

Both. The software is being written by a physicist at no cost to the project.

4. (Reviewer: M. Johnson) I am also concerned about the costs of the devices and the money available. It looked to me that the money was basically adequate but if problems arrise (as they often do), you could come up short.

OK

5. (Reviewer: T. Kobilarcik) I did not see any data showing what is achievable using existing systems (perhaps this was shown at a previous meeting). How long a stretch is it from what we do now to what NuMI needs?

All instrumentation is standard except for the low loss profile monitors.

6. (Reviewer: T. Kobilarcik) Does a plan exist for testing a prototype in an operating beamline/transfer line?

The profile monitors were tested in the MiniBooNE beamline.

7. (Reviewer: A. Marchionni) At this stage I think we still need to answer some basic questions, which have an impact mainly on the required reliability and redundancy of the instrumentation:

   a. Is the use a collimator in the very upstream part of the beam line completely excluded ? Was it ever done a MARS calculation? One might want to wait to know how "bad" the beam is from the P150 tests, but a working collimator would alleviate some of the "pressure" on the downstream part of the beam line.
   b. What's the effect of combined current variations in several power supplies? Is it really true that in the lined region of the carrier tunnel "geometry constraints preclude direct primary beam loss" ?
   c. Given the strict stability requested for the power supplies (60 ppm for major bends and 200 ppm for smaller bends), how essential is Autotune for groundwater protection ? And if it is essential, do we have any redundancy in the BPM system ? Do we have BPM's in all of the critical locations ?

These comments are addressed in the response to Bill Foster's comments above.

8. (Reviewer: A. Marchionni) No specifications for the data logging of the instrumentation have been given: which is the valuable information that we want to save for the experiment ?

The list of information to be transferred to the experiment is being developed.

9. (Reviewer: A. Marchionni) No mention has been made of the number, location and sensitivity of vacuum gauges. How well will we know the vacuum level in the middle of the carrier tunnel ?

Precise knowledge of the vacuum level in the CT is not needed. The vacuum levels will be far below the minimum requirement of 10^{-6} Torr.

10. (Reviewer: A. Para) Both reviews give an impression that the prevailing attitude is that of ease. It is thought that we have done this kind of things before and we can bring the NuMI proton beam up and maintain it within the tolerances just like we did with KTeV beam. It may be so, but it is impossible for those who are not familiar with the KTeV beamline operation to judge. In particular it is difficult to judge if the extrapolation from the KTeV experience is a valid one. What are the differences in specs? intensities? geometries? sensitivity to mishaps? etc.. Perhaps a short summary of the experience with the KTeV beam would be helpful?

The intent was not to give the impression of "ease", but to demonstrate that the operation of a NuMI/KteV beamline with low losses and precise beam transport is possible with careful design and attention to detail.

11. (Reviewer: A. Para) Requirements on the proton beam steering are coming from two sources: physics and groundwater protection. These requirements were not well separated and frequently used interchangeably. They are used to establish requirements on the beam monitoring devices, some of them being quite demanding.

OK

12. (Reviewer: A. Para) One of the main concerns with the proton beam is that of possible tails extending to larger transverse distances. We do not have any means to monitor such tails. Given their importance, it would be perhaps advisable to have a set of multiwire detectors with few central wires removed. Such detectors could be position in the beam line at all times and they could detect and measure the these tails.

The UT-Austin profile monitors have halo foils included in the design.

13. (Reviewer: A. Para) The primary bam instrumentation will be of critical importance for the commissioning of the proton beam line. There was no mention of the commissioning procedure, hence it is difficult to asses if the proposed instrumentation is adequate.

Commissioning issues were addressed in a later review.

14. (Reviewer: R. Pasquinelli) The tight requirements on momentum spread strongly suggest the use of scrapers just after the beam is extracted from MI. This may not be trivial as problems with bunch rotation could cause excessive losses on these scrapers.

The new optics design does not have tight requirements on the momentum spread.

15. (Reviewer: R. Pasquinelli) Although the project is concentrating on the low energy beam, the experiment is designed for accepting three energies based on horn location. The question was asked whether the instrumentation being reviewed would cover all conditions both initially and in the future. While the answer given was yes, there was no concrete evidence presented to support the response. It may be very difficult to modify the instrumentation systems in the future should there be shortcomings in the current designs.

The primary beam instrumentation only monitors the 120 GeV proton beam. The beam transport is independent of the neutrino energy mode.

16. (Reviewer: B. Webber) Interface to control system needs to be established for each instrumentation system; start by defining what data is required, when, and with what delay.

Done.

Loss Monitors, Multi-Wires, and Toroids
Presenter: G. Tassotto

1. (Reviewer: B. Foster) A wire support frame which is an open “C”-shape (instead of a windowframe design) would have the huge advantage that the frame would not pass through the beam and thus could not be destroyed if the beam were extracted at the wrong time. This would also eliminate the need for electrical interlocks. Both X and Y readout wires could still be supported on a single “C” frame.

The UT-Austin profile monitors use a bayonet design that obviates this problem.

2. (Reviewer: B. Foster) The graphite-wire multiwire would be a useful project if NUMI had the time and people and money to pursue it. It doesn’t. However it should perhaps be pursued as a R&D project in the instrumentation group, or perhaps in PPD since there is a lot of expertise in drift chamber wires out there.

Carbon fibers have been dropped from consideration in preference to thin titanium foils.

3. (Reviewer: B. Foster) The readout granularity of the TLMs should be thought about.

Done

4. (Reviewer: B. Foster) Chuck Brown’s suggestion of scintillator paddles as an “early warning system” for beam halo scraping is a good one.

The UT-Austin profile monitors provide this feature.

5. (Reviewer: M. Johnson) I did not see the need for pursuing carbon fiber elements for the SEMS. It looks to me like a diversion of scarce resources.

We agree.

6. (Reviewer: A. Marchionni) During the presentation of the MW system, the secondary emission coefficient for AuW wires, that is the charge delivered for a given number of protons hitting the wire, has not been given. This makes it impossible to understand if the associated SWIC electronics is suitable or not and which value of integrating capacitors we will need. I understand that there is experience here at the lab with these devices, and that they are working. Still, when I tried to insert a MW in the P150 line, running at `high intensity' (4×10^{12} !), I was not able to get a profile, and I was told that it was a known problem. Clearly more tests, and I say this for myself, are needed there. At this stage, I see the R&D effort on carbon wires as a distraction.

We agree

7. (Reviewer: A. Marchionni) What's the time scale for the development of the new electronics for the toroids ? How do we check for their time stability ?

We are using standard toroid electronics. The precision is acceptable.

8. (Reviewer: A. Marchionni) BLM's are evenly distributed along the beam line, with two exceptions:

    a. after LMQ102, positioned on quadrupole Q102, there are about 50 m with no loss monitors. This is a straight section mainly with no magnets, but with the exception of quadrupole Q103 and trims HC103, VC103.
    b. no BLM's are in the carrier tunnel, but only TLM's. If we see any losses in the TLM's, will we be able to diagnose the problem ?

BLM's are planned for each beamline element. We have decided to put no active devices in the upper part of the carrier tunnel. The TLM's in this area are accessible from outside. If a loss occurs in this region (where there are no BLM's or magnets) the loss can only be due to mis-steered beam upstream of the carrier tunnel.

9. (Reviewer: A. Marchionni) The detectors that will constitute the Beam Loss Budget Monitor must be clearly specified and we must have some way to check that they are working. For TLM's, the use of radioactive sources ensures that they are functioning and provides at the same time a trackable calibration. I think that a `small Cs137' source will not work, it's hard to convert photons. More effective would be the use of an alpha source (Americium 241), as it has been successfully implemented in the PIC muon chambers read out by SWIC electronics (the trick is to integrate the signal for a `long' time out of spill). I don't know how to solve the problem with BLM's: an Am source placed outside of the glass envelope wouldn't work !

The Beam Loss Budget Monitor will utilize signals from the TLM's. A heartbeat system for the TLM's is in development. It will likely consist of an electrode to inject charge into the heliax cable. A heartbeat for the BLM's is not necessary.

10. (Reviewer: A. Marchionni) The dynamic range specified for the loss monitors (from 2×10^{8} to 4×10^{13} proton beam loss), both for BLM's and TLM's, is what's needed to measure losses down to the 10^{-4} level. It has to be seen what that corresponds to in terms of output signal from the detectors, and if it is within the dynamic range of the electronics. Noise levels, especially from TLM's, have to be measured. Some testing, possibly in the P150 line, is required here. The precision with which we want to record losses should be clearly specified too.

The integrating capacitors in the loss monitor electronics may need to be matched to satisfy these requirements. Testing is underway on TLM signal and noise using the Radiation Test Facility.

11. (Reviewer: C. Moore) If loss monitors could be developed with sufficient sensitivity then a possibility would be to have a redundant and fail-safe system that would be akin to a safety system and other measures could be taken care of in the "Ducar Box" which would then have more relaxed criteria for what could be changed from the MCR.

OK

12. (Reviewer: A. Para) Chief problem with the proton beam line is related to the beam losses and potential implications for groundwater. We will monitor losses at the discreet positions using BLM and integrate over long distances using TLM's. Given the integral nature of the measurement it is important to ensure the operational condition of all of these detectors at all times. The long detectors will be monitored using sources, although no details were presented. There was no mention of the monitoring of the BLM's.

See above response.

13. (Reviewer: A. Para) The most sensitive point, from the point of view of groundwater, is the lined interface region, where the losses must be kept below 10^{-6}. They are monitored using the long TLM, which covers less sensitive regions too. I haven't quite understood how will we separate large(r) acceptable losses in the less sensitive region from the small losses in the most sensitive region observed in the same long detector.

The integrating capacitors in the loss monitor electronics may need to be matched to satisfy these requirements.

14. (Reviewer: R. Pasquinelli) Loss monitors were specified to have a range of 10×10^{8} to 10×10^{13} particles on all units. There are two types of loss monitors for two different applications. It will be difficult to have high resolution at high beam losses. This spec should be revisited so that the loss monitors for beam budget monitoring are different from those for interlock purposes and have dynamic ranges modified accordingly.

This is our plan.

BPM System
Presenters: V. Makeev, C. Drennan

1. (Reviewer: C. Brown) The BPM system in particular needs clearer specs on the precision required.

Done

2. (Reviewer: B. Foster) The general strategy of using multiwires for low-to-medium intensity single-batch comissioning, and BPMs only for high-intensity multi-batch

production running, seemed reasonable. This considerably reduces the dynamic range and accuracy required of the BPMs. However, the intensity at which NUMI will have to flip out the multiwires and switch to BPM's-only should be clearly stated understood and documented. This may differ from station to station along the line.

The maximum intensity for operation with profile monitors will be determined by the NuMI beam permit system.

3. (Reviewer: B. Foster) The BPM dynamic range is only a factor of ~3 in beam current, since most of the intensity increase (from multiwire comissioning to production running) comes from more/longer batches not higher beam current That having been said, it might be a good idea for the electronics to tolerate slightly higher beam current (~2x Main Injector nominal intensity or ~12E10 ppb?).

Done

4. (Reviewer: B. Foster) The BPM system accuracy specification is overstated. The only real requirement is that the position signal remain stable as the multiwires are flipped out and the beam current is raised by a factor of ~3 as discussed above. Moreover this BPM stability requirement only applies when the beam is well centered, since the beam position will be established with the multiwires.

OK

5. (Reviewer: B. Foster) Any new BPM electronics should be tested for sensitivity to beam loss. Specifically, the BPM position signal should not change when the nearby multiwire is flipped in or out. It should also be tested to make sure that it is not fried when the beam hits the signal plates.

We do not anticipate any different behavior with the new electronics compared to the existing electronics. We will check for this effect during commissioning however.

6. (Reviewer: M. Johnson) The reduced (10 DB) dynamic range should make using the rack monitor to process the BPM information feasible. If the dynamic range were to increase substantially, then I would worry a bit about a lot of common mode noise affecting the input signals.

We are using standalone BPM electronics based on the plans for the Recycler and Main Injector electronics upgrades.

7. (Reviewer: T. Kobilarcik) How robust is the autotune algorithm in regard to non-uniform errors or non-linear response in the same device? For a given BPM, how far can the beam move before the rms error is the same size as the correction? How far can the beam move before a convergent solution is no longer possible due to errors, that is, what is the "tuning window" defined by the instrumentation? How does this window compare the the expected centroid rms due to power supply ripple, extraction errors, and such?

Autotune has been successfully used in a variety of other beamlines. The application to NuMI does not “push the envelope” in terms of errors or accuracy.

8. (Reviewer: A. Marchionni) The BPM area seems to be well covered and reasonably well understood. Several important open problems need to be addressed for MW's and loss monitors:

    a. dynamic range and details of the readout electronics for MW's and loss monitors
    b. availability of BLM's and construction of TLM's
    c. implementation of `heart beat' for TLM's.

These are all being addressed.

9. (Reviewer: A. Marchionni) Concerning the locations of the BPM's, the scheme adopted here is to always place BPM's in pairs, differently from what it is done e.g. in P150, where horizontal BPM's are always positioned after focusing quadrupoles and vertical BPM's after defocusing quadrupoles. In the adopted scheme, quadrupoles Q102, Q105 and Q109 have no instrumentation nearby. In particular in the pretarget area the beam is transported for about 40 m through dipoles, quadrupoles and trims without any positioning instrumentation.

Additional instrumentation has been added in the re-design beam optics.

10. (Reviewer: A. Marchionni) I do not understand the requirement of 50 micron resolution on the last 2 BPM stations. With the given geometry, such a resolution corresponds to a resolution on the target of 100 micron with an angular resolution of 5 microrad. I believe that 100 micron resolution for the targeting BPM's would be more appropriate. In this case, is it really necessary to have the targeting BPM's a factor 2 smaller in diameter than the other ones ? Since the response of the devices is adversely affected by beam hitting them, it might be safer to make them larger. I would retain the feature of software selectable attenuators in the readout electronics to increase the dynamic range. It's not yet clear what our `full' intensity will be, at the least in the first stage, and we have anyhow to test Autotune at lower intensities. I did not understand the details of the calibration of the BPM system.

We have included a safety margin in the resolution specification to account for the inevitable resolution loss real devices suffer from in the field. Simulations have demonstrated that the 2” aperture of the target BPM’s is more than sufficient.

11. (Reviewer: A. Para) Proton beam position will be monitored by multiwires and BPM's. The requirements on the position accuracy of BPM's is 200 microns and 50 microns, dependent of the location. It is quite difficult to understand the origin of these requirements, especially that of 50 microns. Many people seem to be

confused into thinking that the proton beam must be pointing towards the far detector (as indeed, 50 microns BPM's separated by 14 meters could ensure).

See above response.

12. (Reviewer: R. Pasquinelli) The BPM systems look to have been incorrectly specified to the engineers. The specification for beam is $3\text{-}9.5\times10^{10}$ protons per bunch. This is only a 10 dB dynamic range. Yet the engineers are designing a system with front end gain switching to handle much larger ranges at added complexity and cost. The BPM electronics should be redesigned for this smaller requirement by eliminating the front end switches and variable attenuators.

Done

13. (Reviewer: R. Pasquinelli) It has been decided to use IRMs for the data collection of the BPMs. IRMs have a good track record. The two individuals in controls that have supported this system are either retiring or close to it. The Beams Division must see that additional personnel are assigned to supporting this system, as it is also integral to Linac operations.

We are not using IRM's.

14. (Reviewer: B. Webber) BPM requirements need attention -- why does there seem to be so much effort going into dynamic range effects when the specified range in beam currents is only a factor of 3? is specifed resolution really required over full range of beam positions? will BPMs be required to work with short-batch (i.e. less than ~80 beam bunches) beam during commissioning and/or troubleshooting operations?

See above responses.